science for a changing world

2011 Floods and Flood Frequency Analyses

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Data presented in these slides are provisional.

Flood Frequency Analyses

- What are flood frequency analyses and where do the data come from?
- Why are flood frequency analyses important?
- Why do we use 1% Annual Exceedance Probability instead of 100-year?
- Why are 1% AEP flood values changed?
- Where (and why) are flood data more important to gather?
- Why are gages discontinued?
- Why is 2011 so important to flood frequency analyses?

USGS

Flood Frequency Analyses

- Study in cooperation with Montana Department of Transportation and Montana Department of Natural Resources and Conservation
- Update flood frequencies to include data through 2011
- Summarize data in report and provide through Streamstats

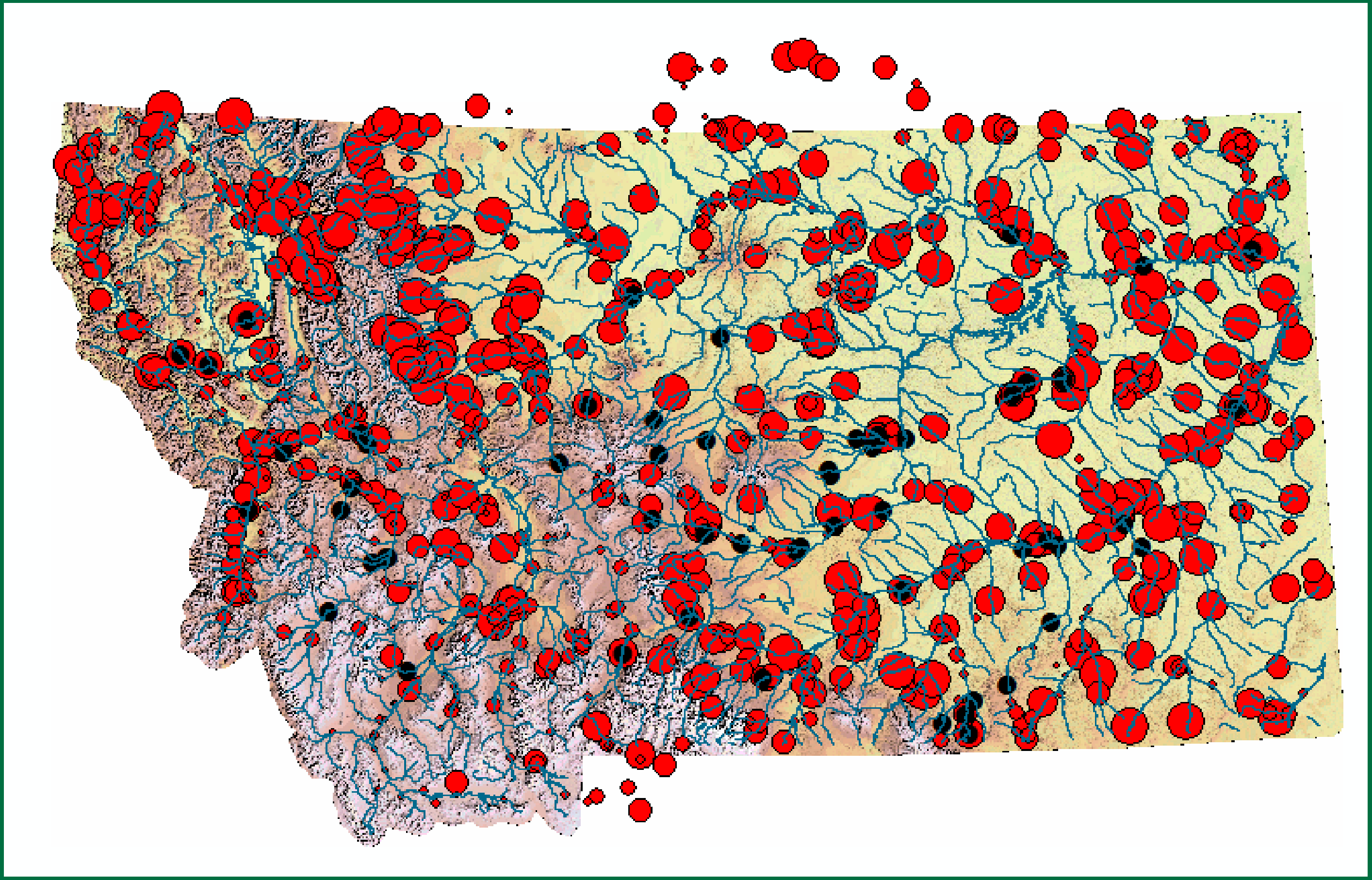
2011 Flooding-

“How big was it?” **and** *“Is that big?”*

The Musselshell Riverfloods homes and farms near Martinsdale, Montana

LARRY MAYER\Gazette Staff

2011 Peaks of Record (Discharge, Provisional)



EXPLANATION

Maximum recorded peak flow normalized to drainage area; Size of circle is proportional to magnitude

Stations with maximum recorded peak occurring in 2011, n~54

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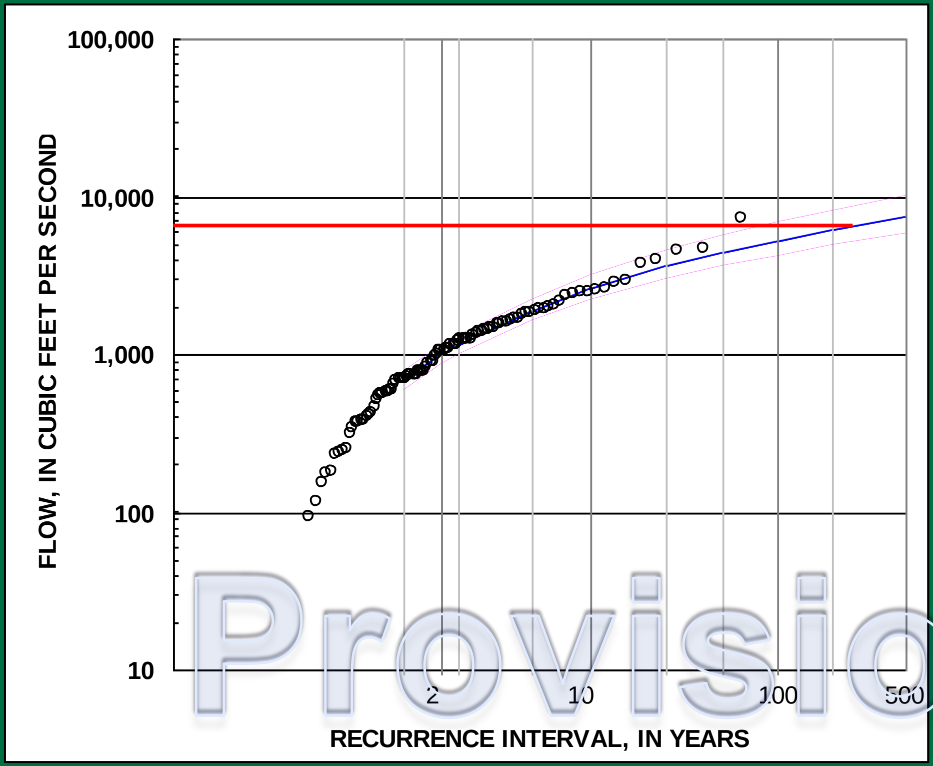
Musselshell River at Harlowton

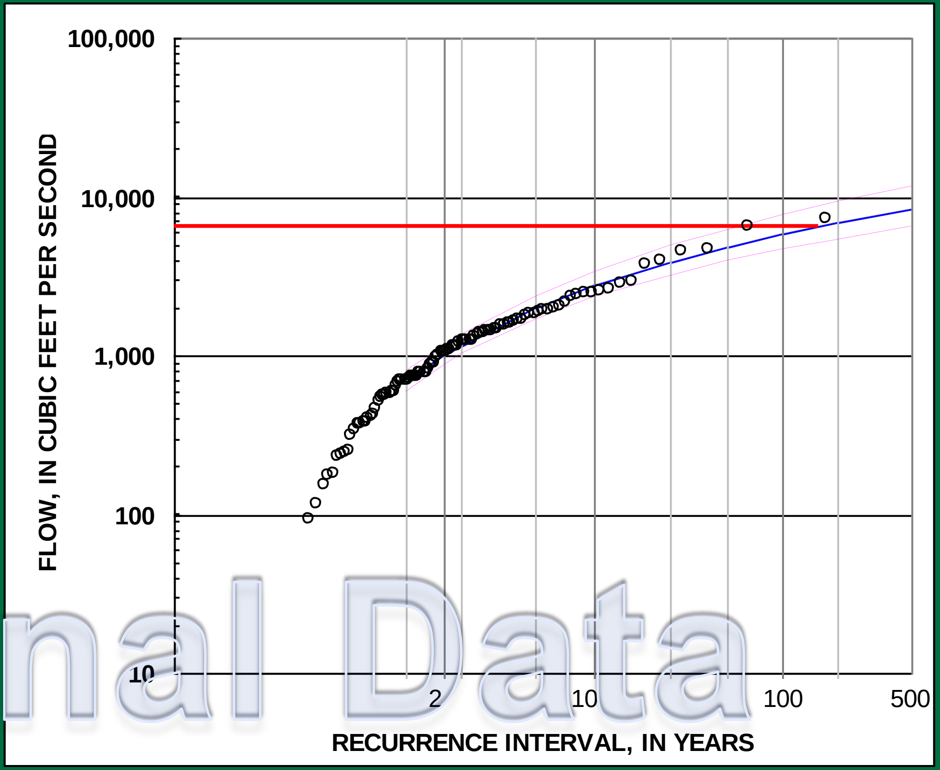
- Gaged 1909-Present
- 2011 Peak Discharge ~6,600 cfs

FFA 1909-2009 (102 yrs)
0.4% Flood (~258 yr)
1% Q=5,290 cfs



FFA 1909-2011 (104 yrs)
0.6% Flood (~157 yr)
1% Q=5,840 cfs

10.4%



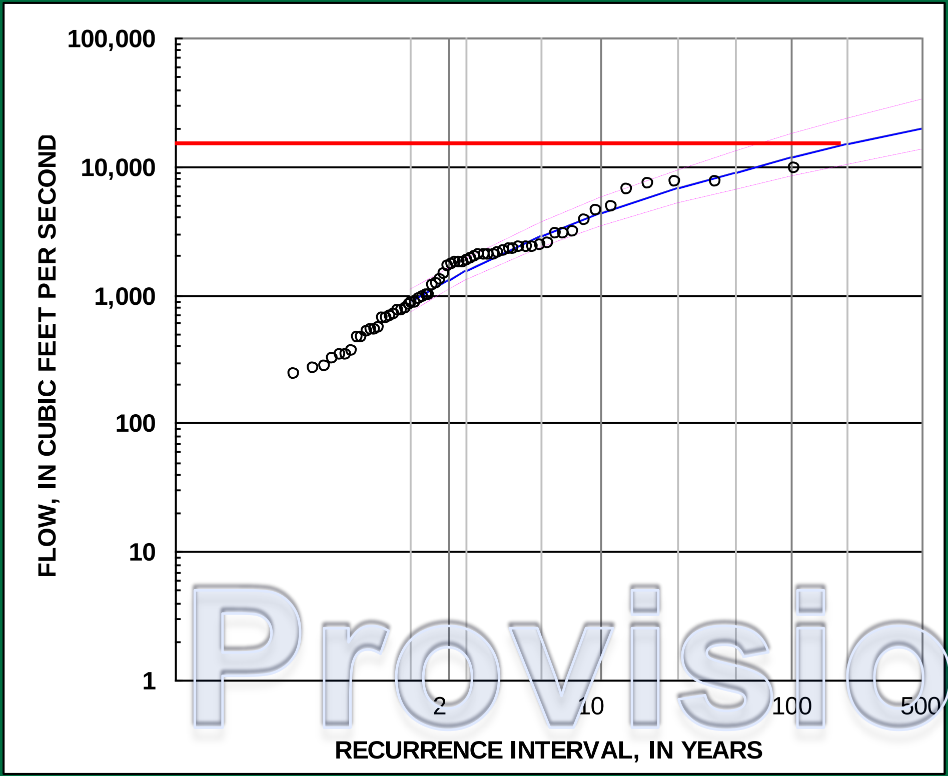
Musselshell River near Roundup

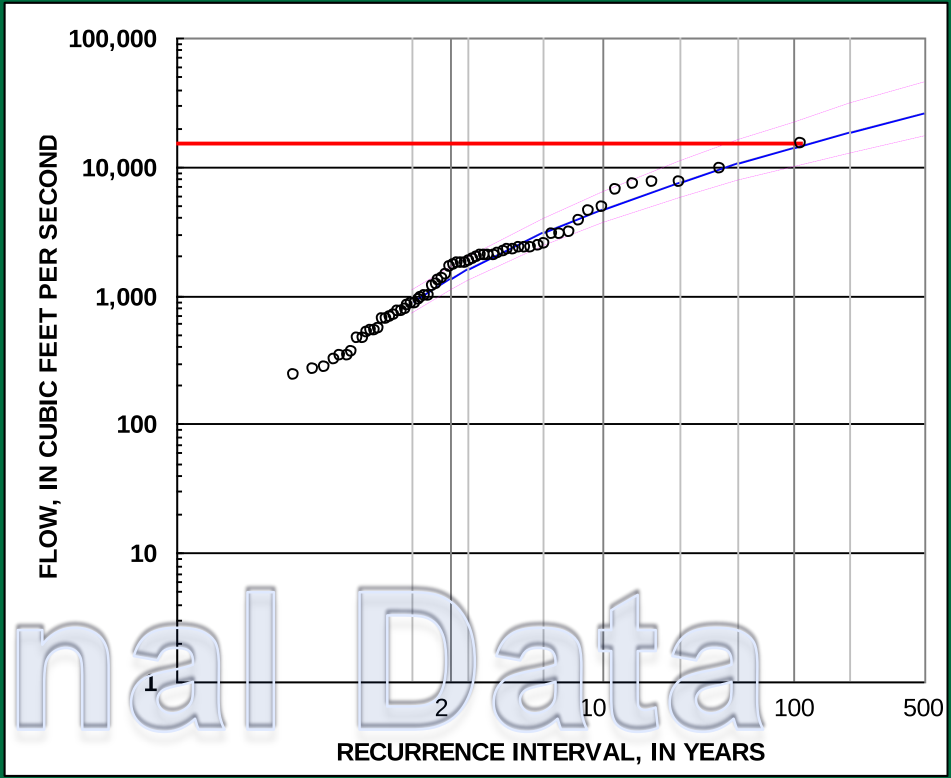
- Gaged 1946-1948, 1950-Present
- 2011 Peak Discharge ~15,100 cfs

FFA 1946-2009 (63 yrs)
0.54% Flood (~185 yr)
1% Q=11,600 cfs

FFA 1946-2011 (65 yrs)
0.85% Flood (~118 yr)
1% Q=14,190 cfs

22.3%

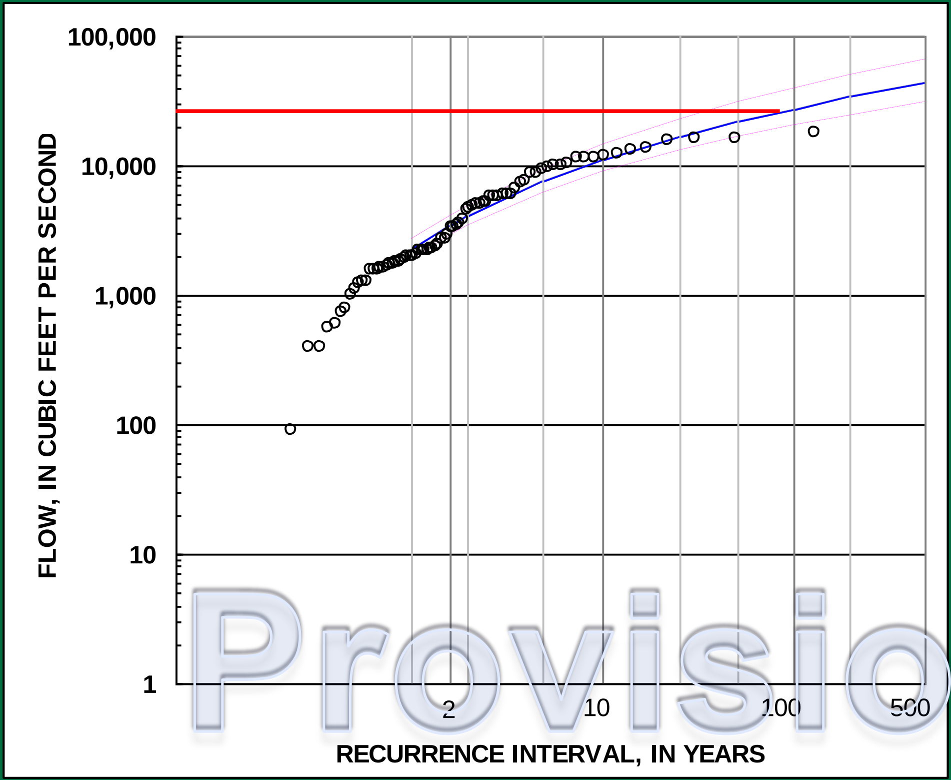




Musselshell River at Mosby

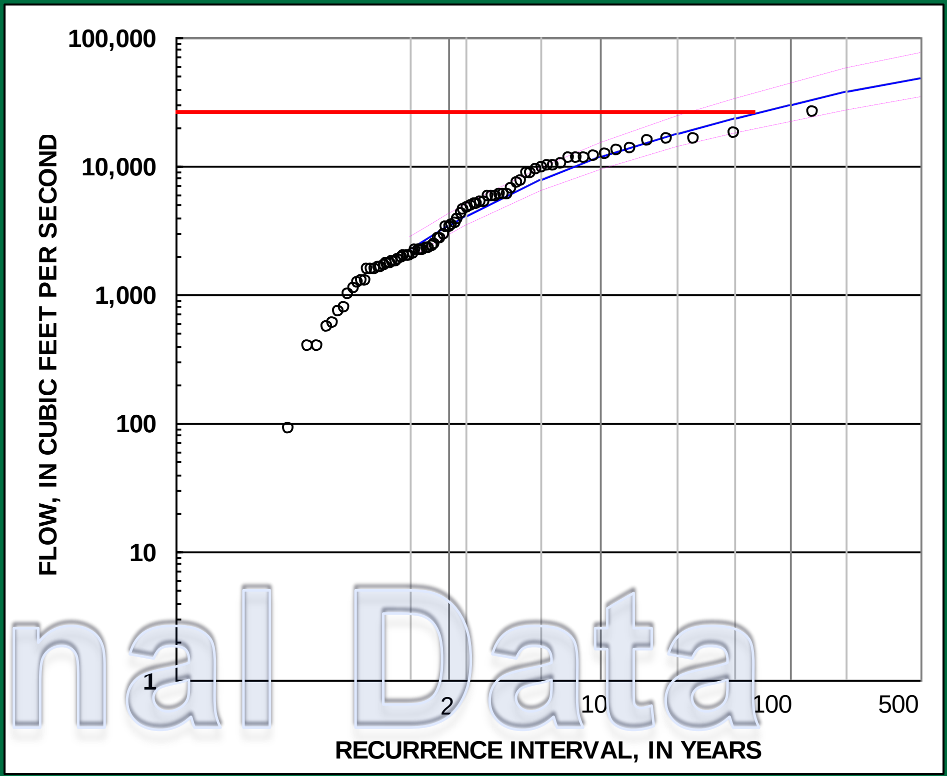
- Gaged 1929, 1932, 1934-46, 1948-Present
- 2011 Peak Discharge ~25,900 cfs

FFA 1929-2009 (78 yrs)
1.2% Flood (~84 yr)
1% Q=27,500 cfs



FFA 1929-2011 (80 yrs)
1.5% Flood (~67 yr)
1% Q=30,300 cfs

10.2%



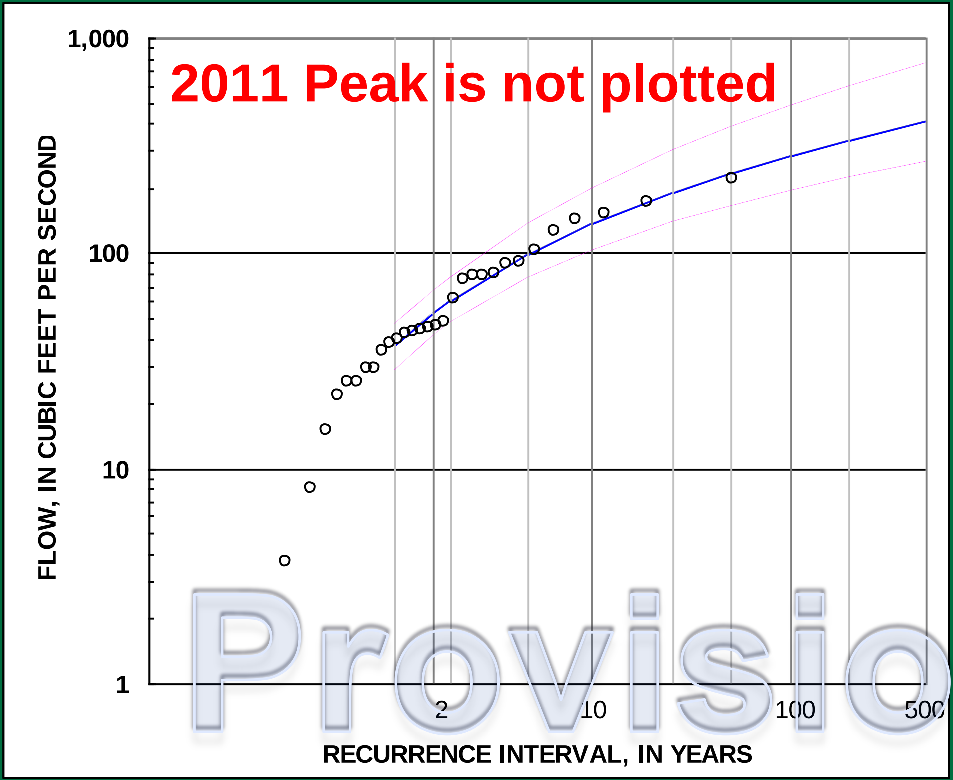
Rosebud Creek near Kirby

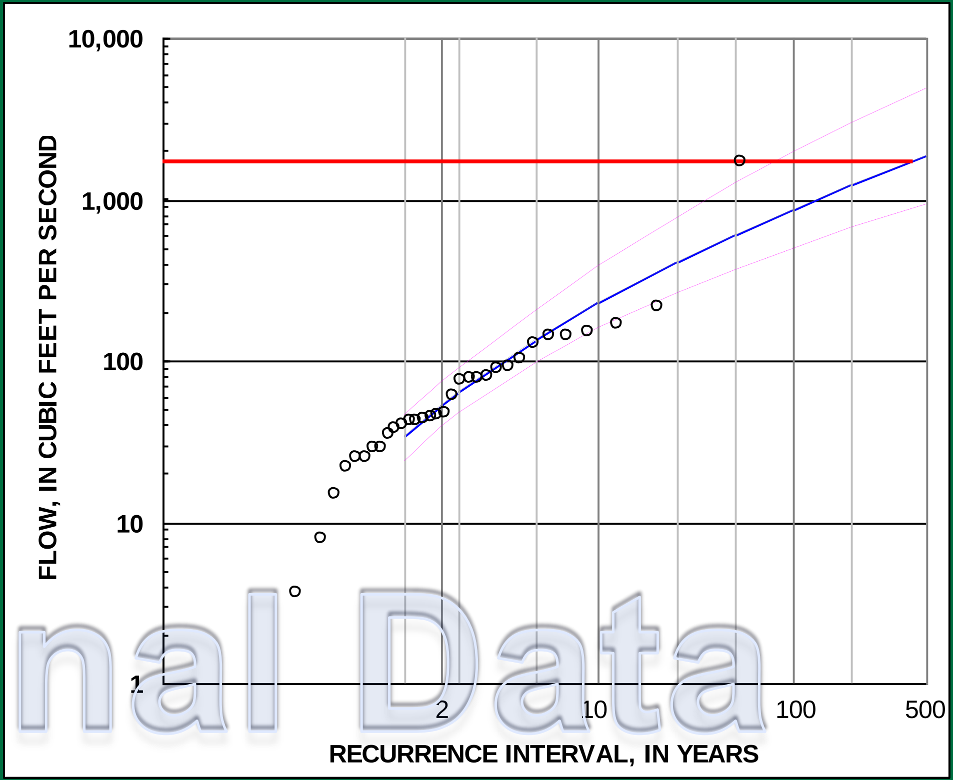
- Gaged 1980-Present
- 2011 Peak Discharge ~1,690 cfs

FFA 1980-2009 (30 yrs)
(Frequency not determined)
1% Q=285 cfs

FFA 1980-2011 (32 yrs)
0.24% Flood (~417 yr)
1% Q=870 cfs

205%



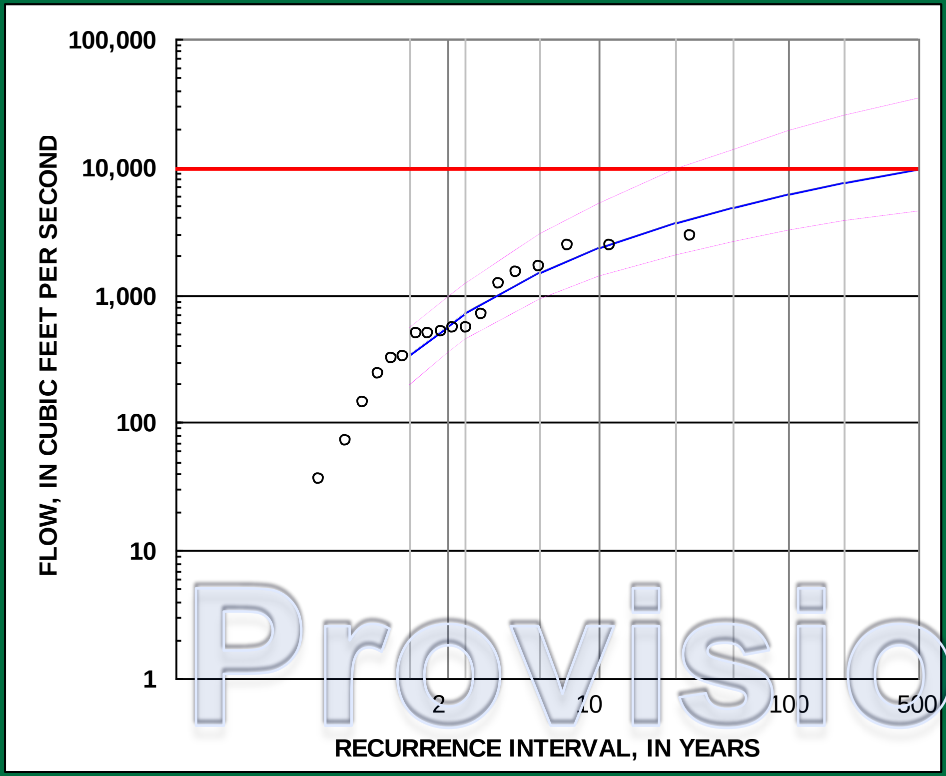


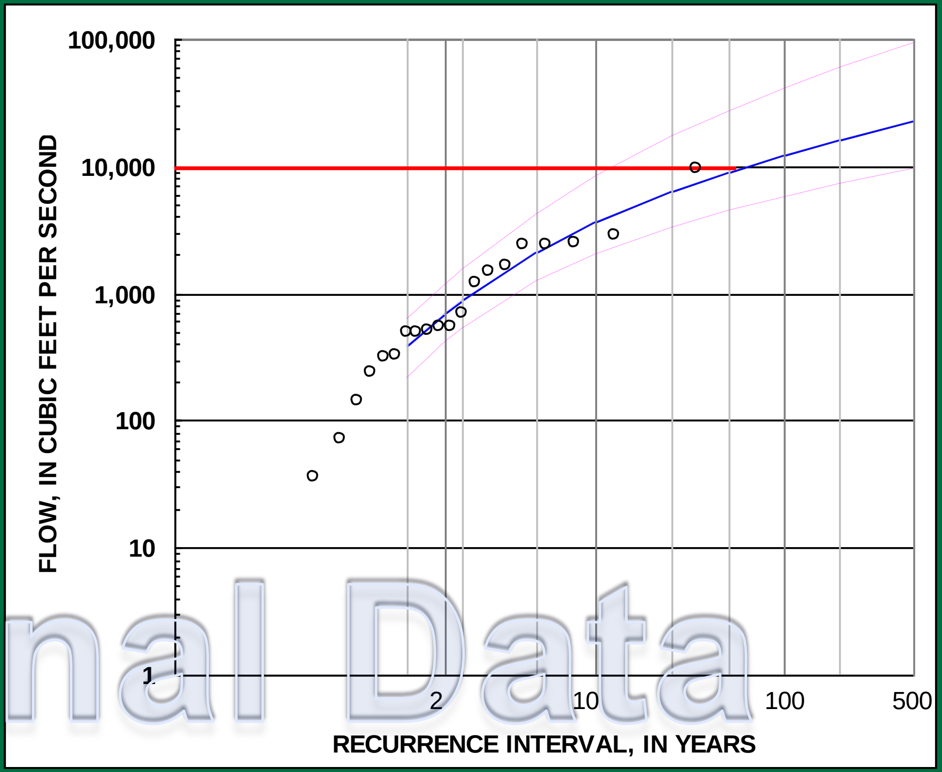
Pumpkin Creek near Miles City

- Gaged 1973-78, 1980-85, 2004-Present
- 2011 Peak Discharge ~9,590 cfs

FFA 1973-2009 (18 yrs)
0.2% Flood (~500 yr)
1% Q=6,210 cfs

FFA 1973-2011 (20 yrs)
1.8% Flood (~55 yr)
1% Q=12,320 cfs **98.4%**

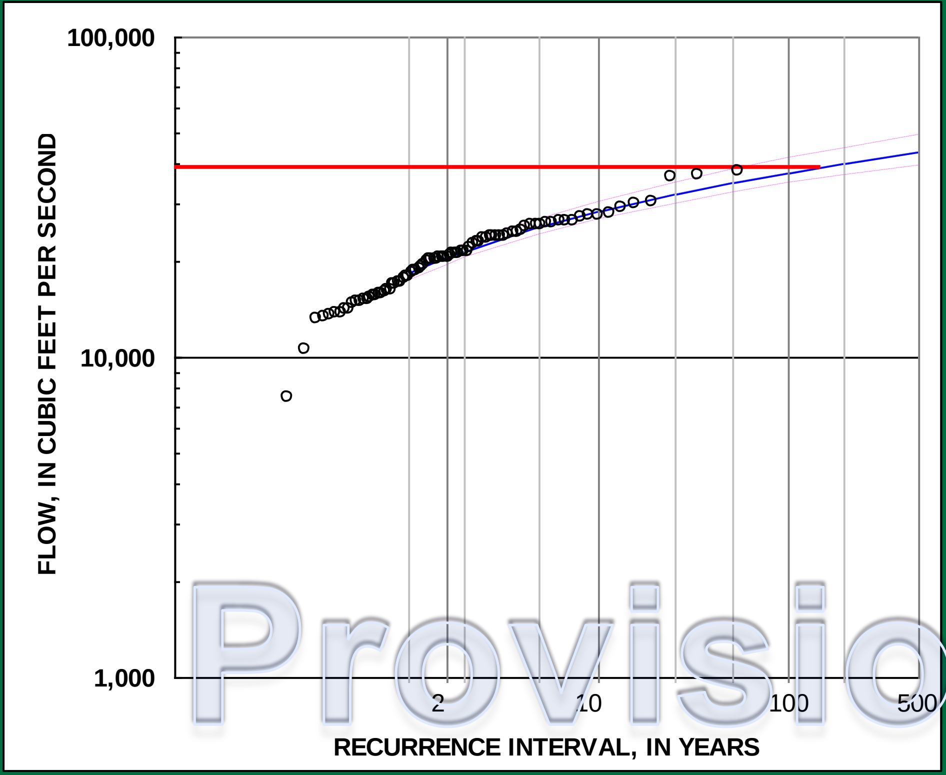




Yellowstone River near Livingston

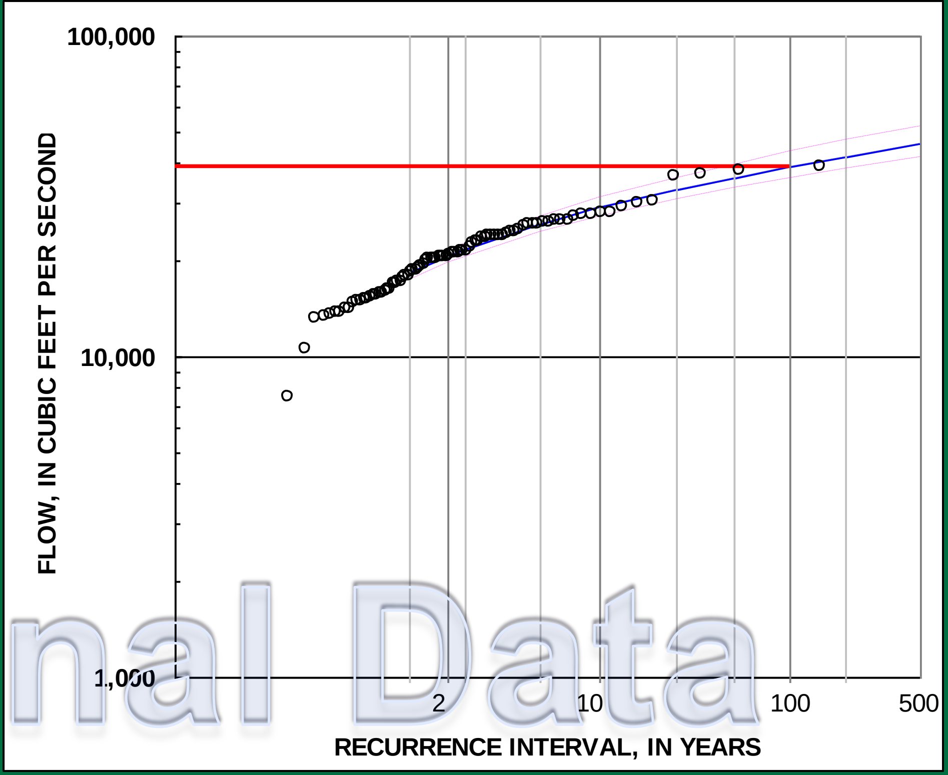
- Gaged 1897-1905, 1929-1932, 1938-Present
- 2011 Peak Discharge ~38,900 cfs

FFA 1897-2009 (86 yrs)
0.68% Flood (~147 yr)
1% Q=37,750 cfs



FFA 1897-2011 (88 yrs)
1.01% Flood (99 yr)
1% Q=39,230 cfs

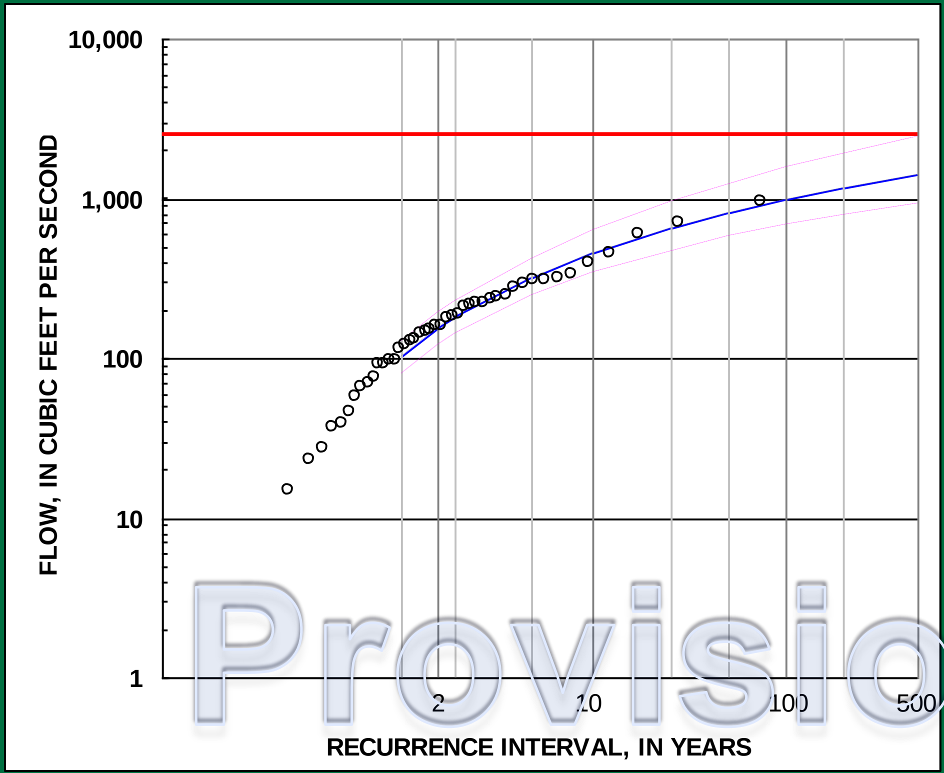
3.9%



Flatwillow Creek near Flatwillow

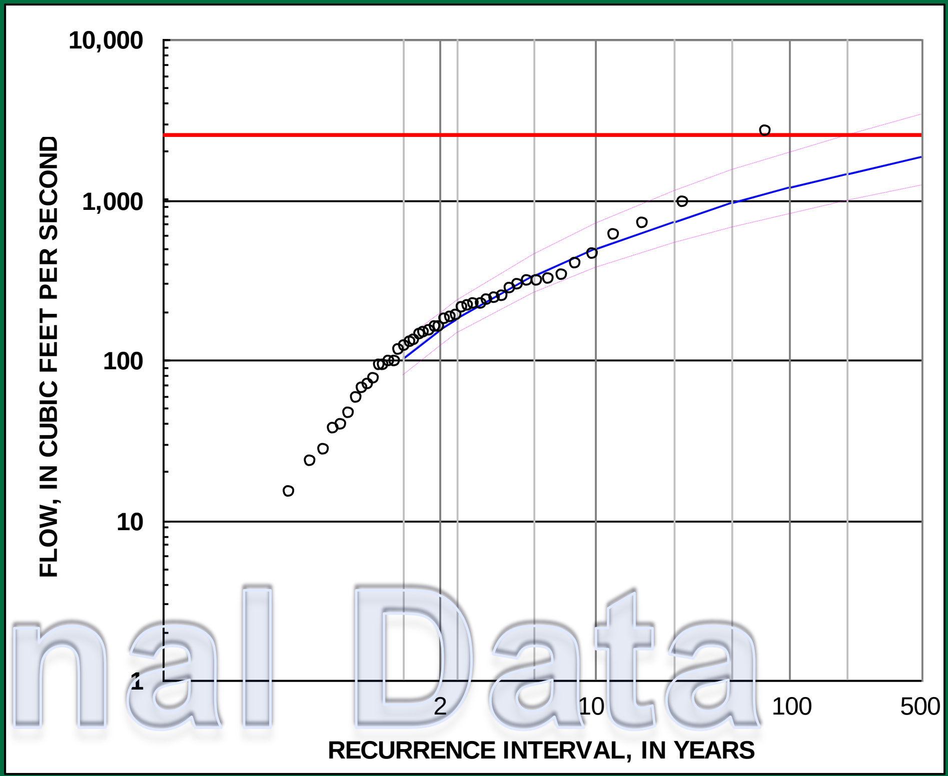
- Gaged 1911-32, 1934-36, 1938-1956
- 2011 Peak Discharge ~2,490 cfs

FFA 1911-1956 (44 yrs)
(Frequency not determined; >500 yr)
1% Q=973 cfs

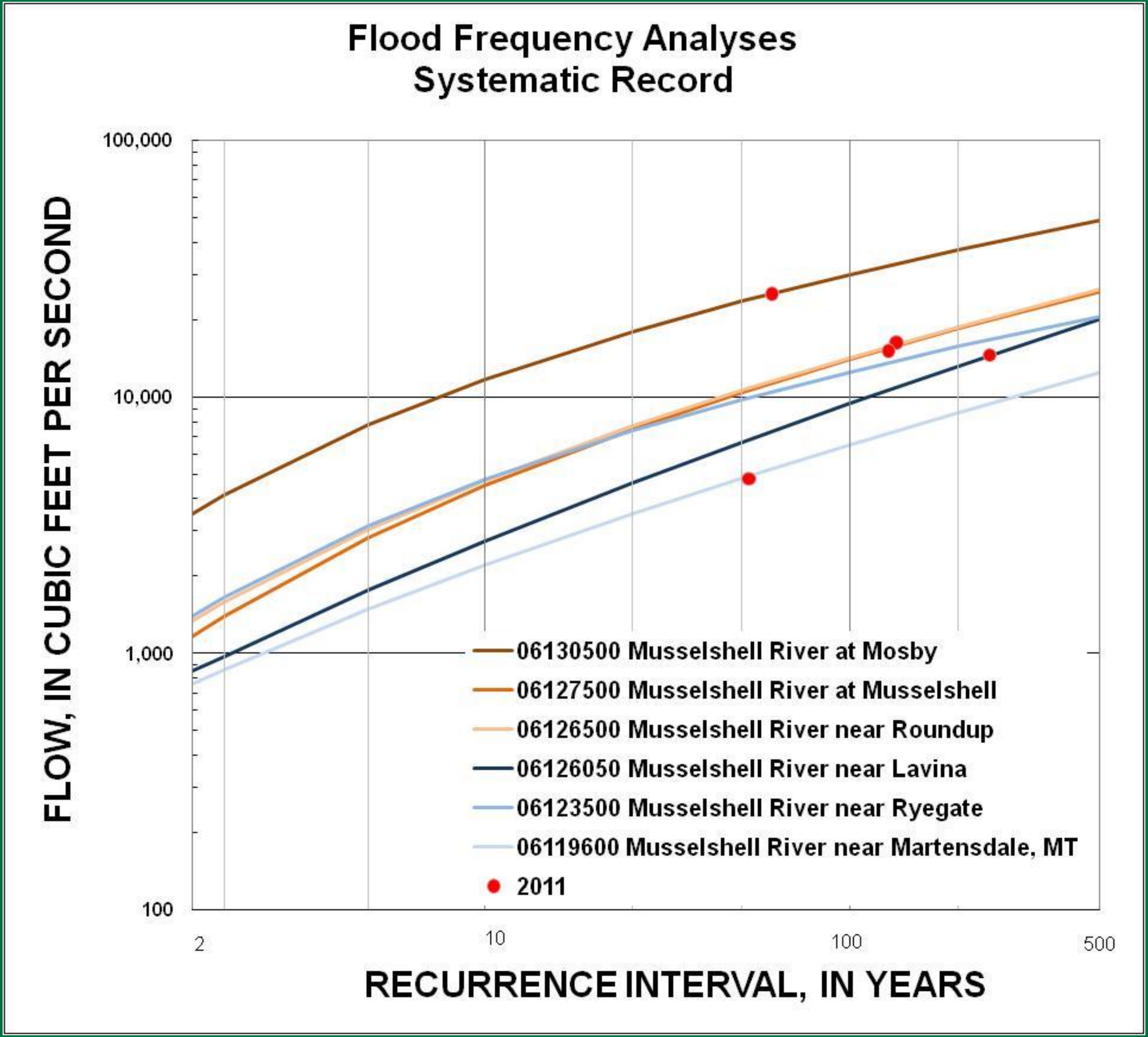


FFA 1911-1956, 2011 (45 yrs)
(Frequency not determined; >500 yr)
1% Q=1,200 cfs

23.3%



Musselshell River-Systematic Record



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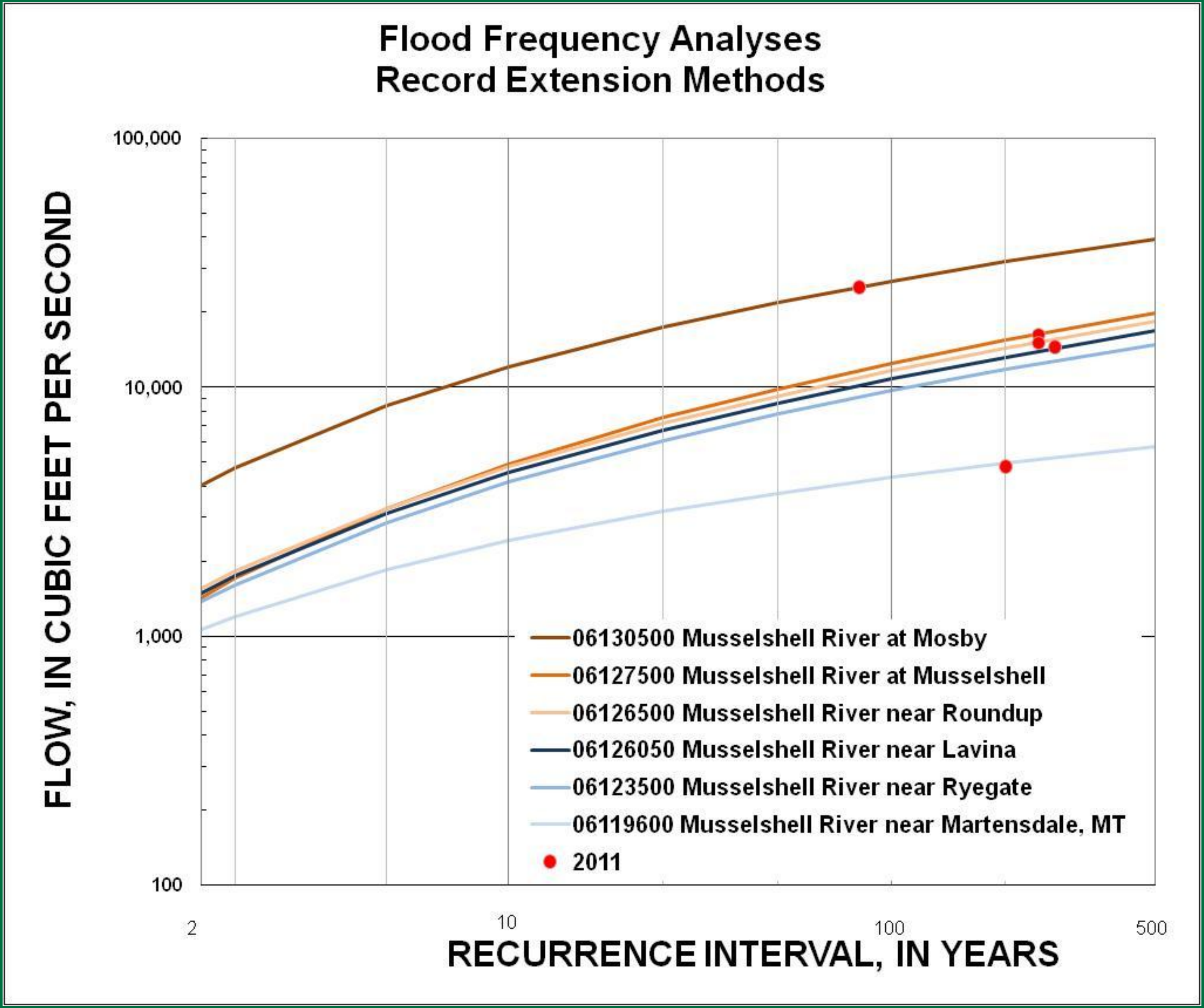
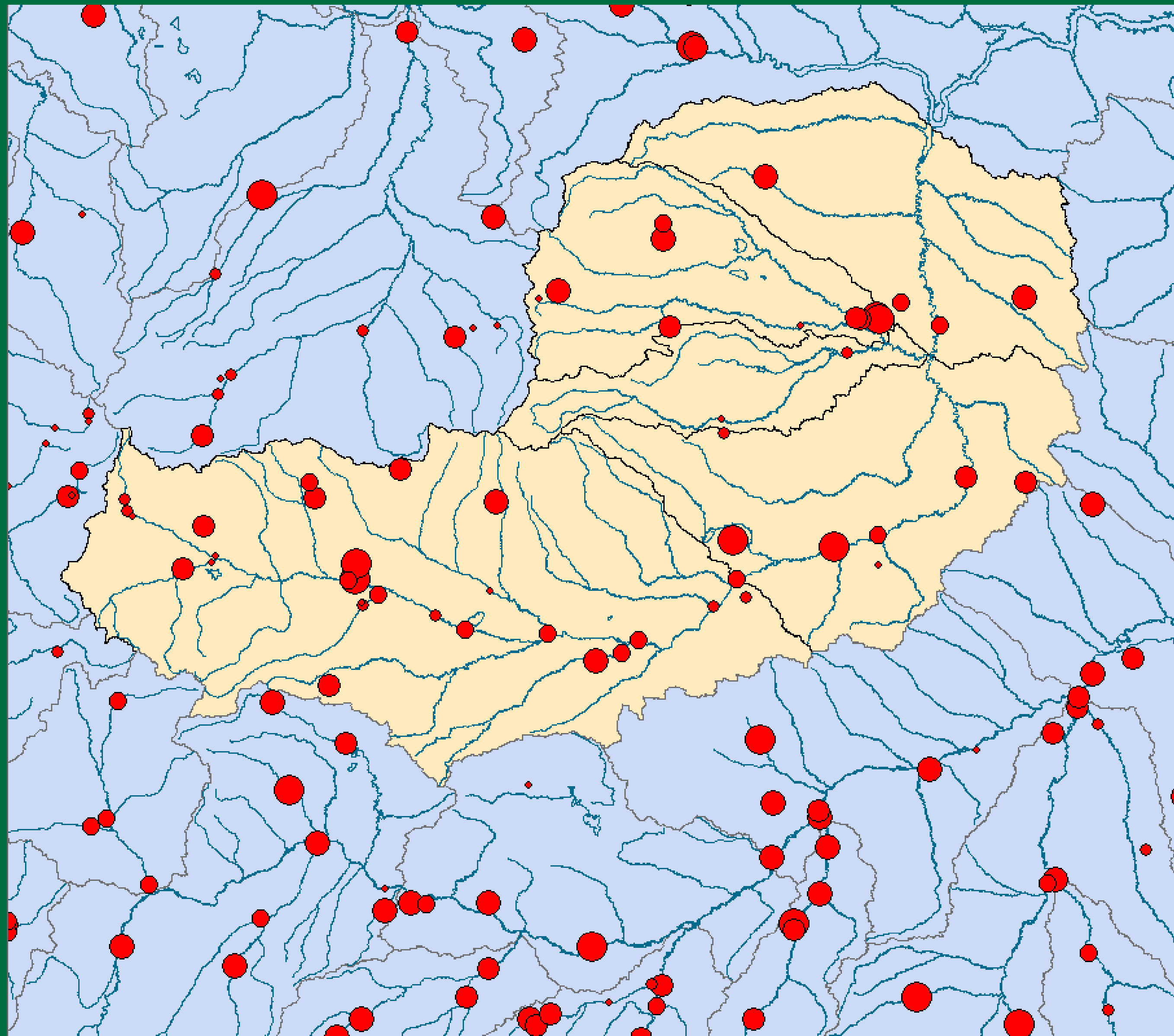
Musselshell River-Record Extension



USGS

Musselshell Basin-Normalized Peaks

Peaks of record for all stream gages (active and discontinued)



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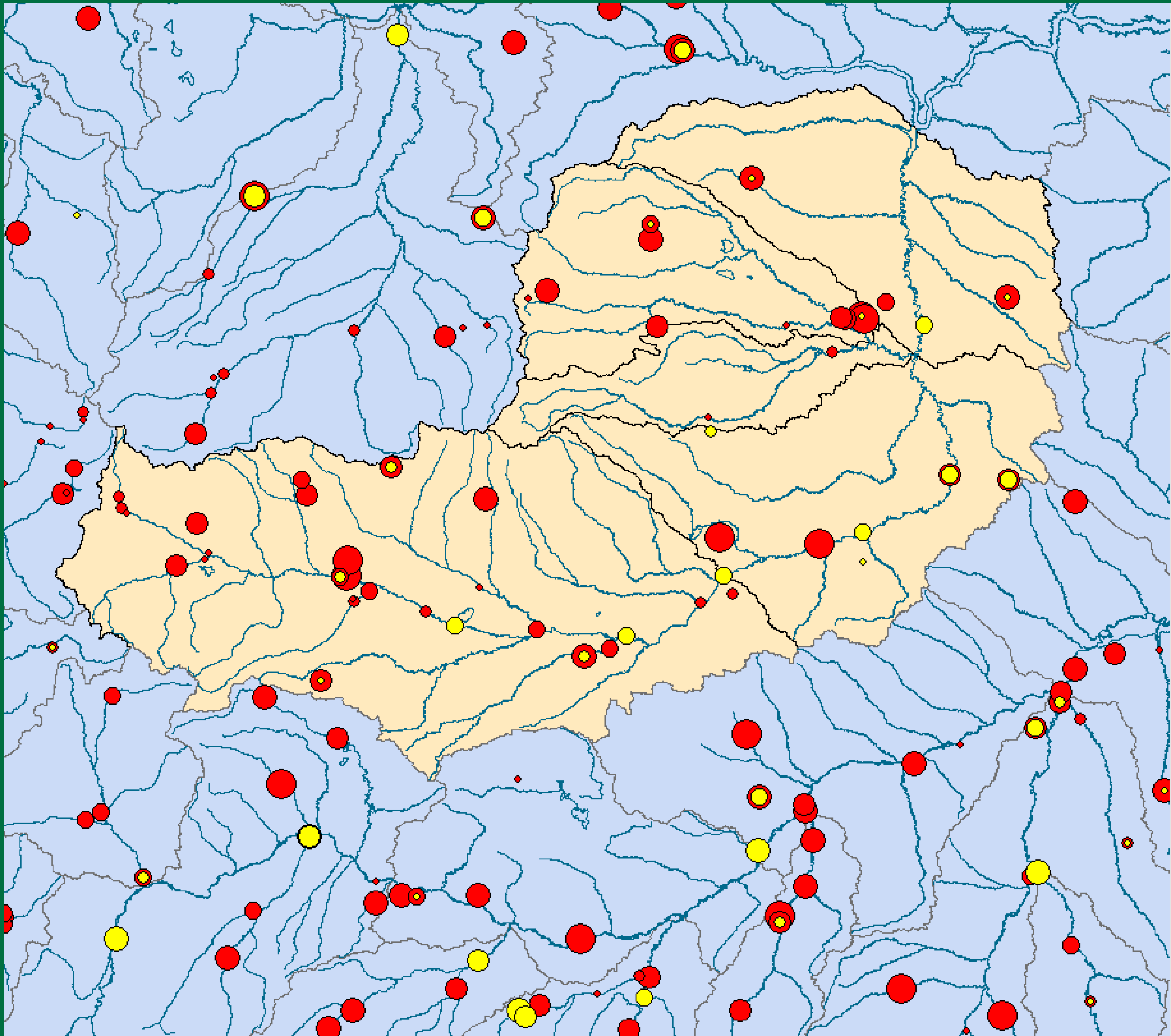
Musselshell Basin-Normalized Peaks

Peaks of record for all stream gages (active and discontinued) with 2011 peaks superimposed



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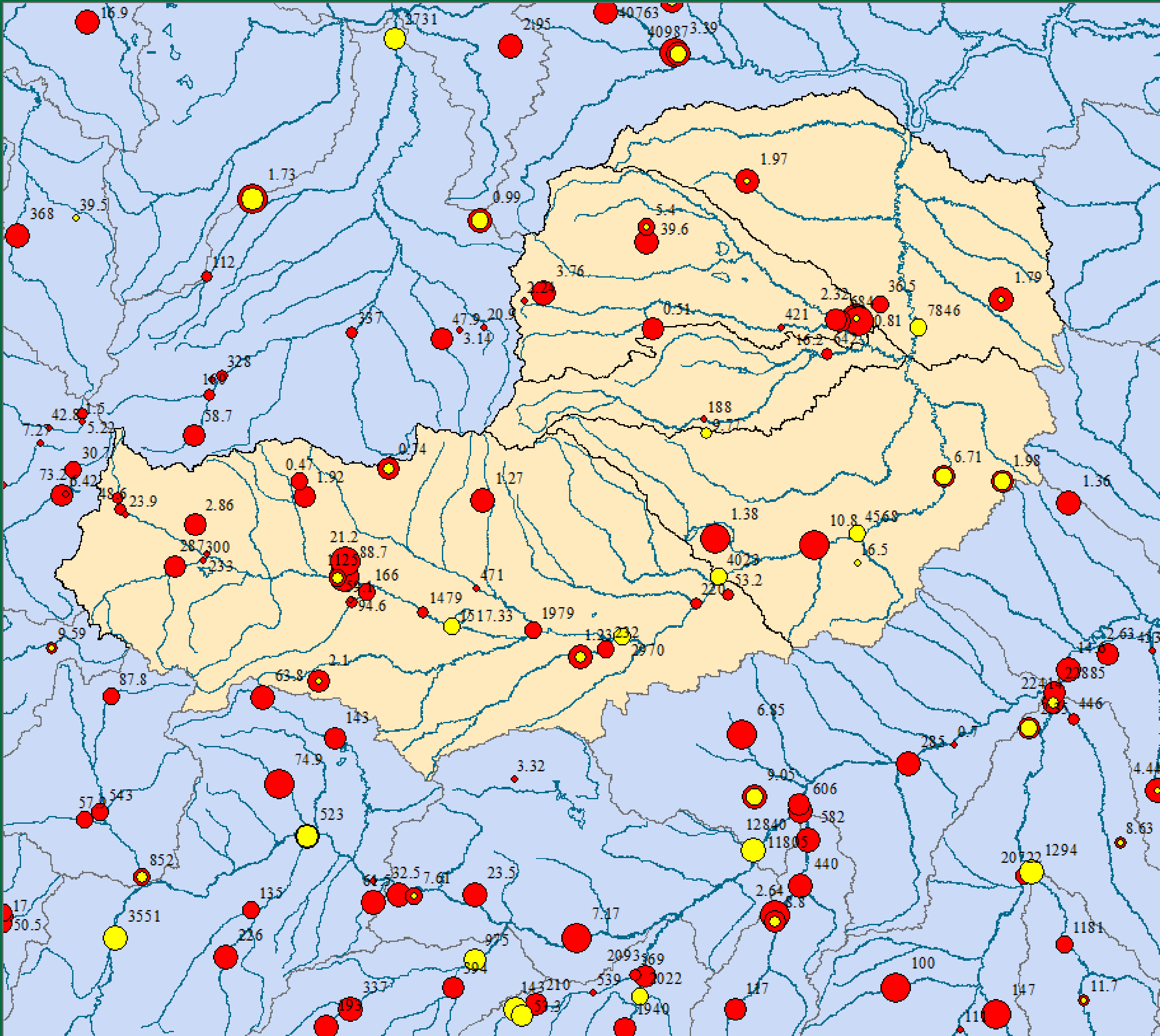
Musselshell Basin-Normalized Peaks

Peaks of record for all stream gages (active and discontinued) with 2011 peaks superimposed; showing drainage areas



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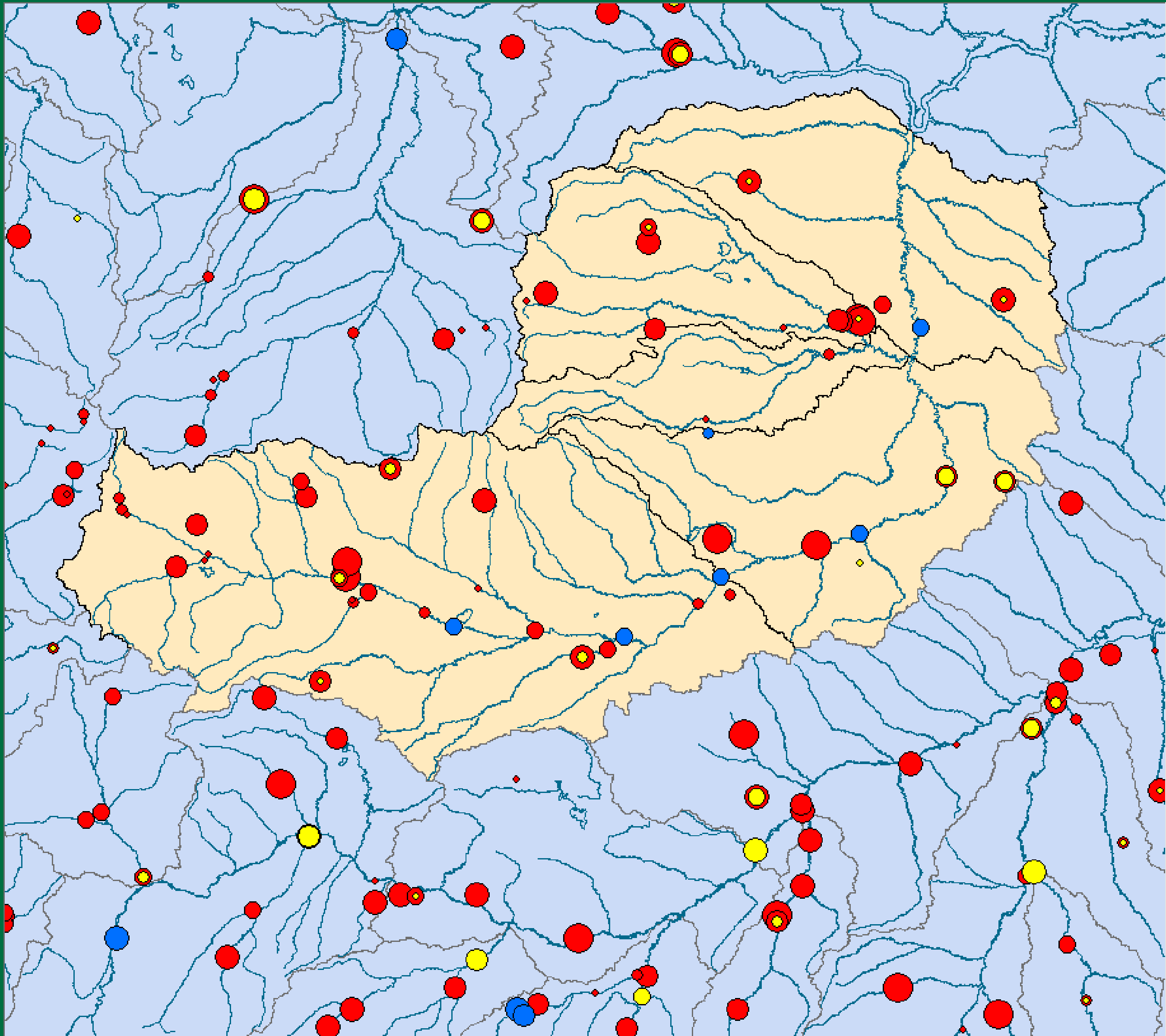
Musselshell Basin-Normalized Peaks

Peaks of record for all stream gages (active and discontinued) with 2011 peaks superimposed; 2011 peaks of record in blue



Questions on flood frequency?

Gibson Dam on the Sun River
June, 1964

Photograph taken by George F. Roskie, Lewis and Clark National Forest

Swiftcurrent Creek at Many Glacier, GNP
November 7, 2006

Photograph taken by Don Bischoff, U.S. Geological Survey, Helena, MT.

Indirect Discharge Measurements

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Data presented in these slides are provisional.

Indirect Measurements

- Computations of peak discharge without using conventional measurement equipment
- Based on high water marks and conservation of energy principles
- Basic types
  - Slope-area
  - Width (bridge) contraction
  - Culvert analysis
  - Road overflow (similar to broad-crested weir)
  - Combination of any or all of the above!

USGS

Slope-area

- Uses channel conveyance based on high water marks to compute discharge
- Site data:
  - High water marks (HWMs) along both banks
  - Manning's n values (roughness estimates) for channel and overbanks
  - Minimum 3 cross sections, more is better

Flatwillow Creek near Winnett – (30 Miles north of Roundup)

USGS

Flatwillow Creek near Winnett: Approximate Cross Section Locations

Flatwillow Creek near Winnett

DISCHARGE COMPUTATIONS

		Reach length (ft)	Discharge (cfs)	Spread (%)	HF (ft)	CX	RC	RX	ER
		176.	6024.	0	0.254	1.000	2.146	0.000	#
		208.	6501.	0	0.553	1.000	1.531	0.000	@#
		230.	6457.	13	0.903	0.934	0.000	-0.228	#
		211.	6082.	0	1.205	0.998	0.000	-0.008	@#
		384.	6315.	0	0.801	1.000	1.745	0.000	@#
		438.	6485.	4	1.461	0.976	0.577	-0.142	@#
SEC3 - SEC5	2.00	441.	6224.	5	2.101	0.975	0.000	-0.096	@
SEC1 - SEC4	3.00	614.	6352.	3	1.684	0.983	0.840	-0.118	@
SEC2 - SEC5	3.40	649.	6334.	3	2.701	0.985	0.298	-0.077	@
SEC1 - SEC5	4.20	825.	6271.	2	2.923	0.988	0.472	-0.070	@

Definitions:
Spread, the percent difference between discharge computed with no expansion loss (k=0) and discharge computed with full expansion loss (k=1.0), divided by the discharge computed with full expansion loss
HF, friction head- HF = sum of Q*Q*L/(K1*K2) over subreaches; Q, discharge; L, reach length; K1, upstream section conveyance; K2, downstream section conveyance
CX, the computed discharge divided by the discharge computed with no expansion loss (k=0)
RC, velocity head change in contracting section divided by friction head
RX, velocity head change in expanding section divided by friction head
ER, warnings, *-fall < 0.5ft, @-conveyance ratio exceeded, #-reach too short error, 1-negative or 0 fall
******, terms that can not be computed because of strong expansion in reach

CROSS SECTION PROPERTIES

- Q= 6,270 cfs

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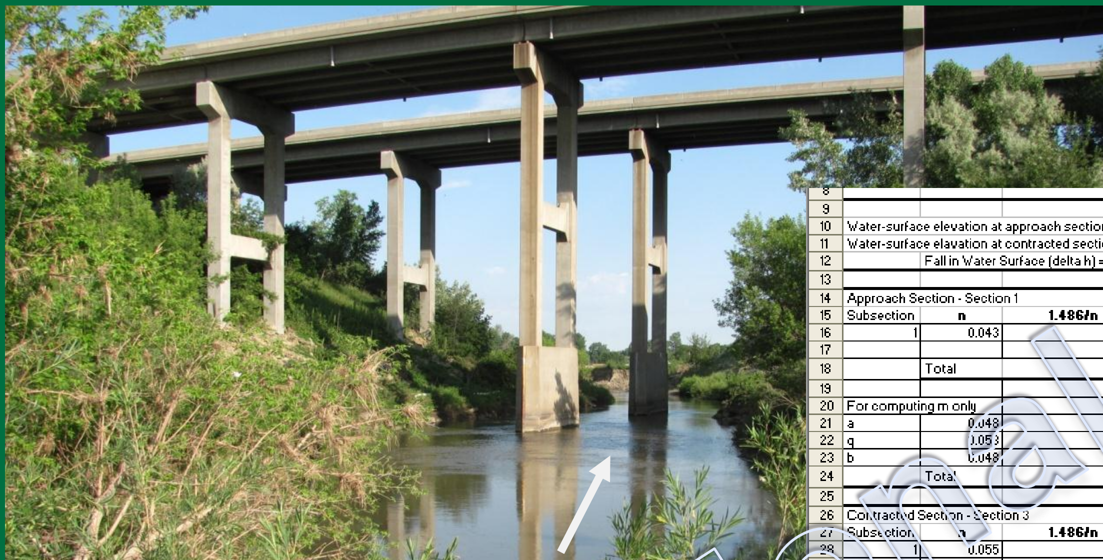
Width (Bridge) Contraction

- Uses energy loss through bridge
- Site data:
  - I-94 NE of Billings
  - Fall through contraction
  - Substantial contraction of channel width
  - Survey contraction section data (piers, low steel, n values)
  - Approach section data
  - HWMs from approach through contraction

Pryor Creek near Huntley

Pryor Creek near Huntley



- Q=7,460 cfs

8										
9				Left	Right	Average	Characteristics of constriction			
10	Water-surface elevation at approach section			3031.50	3031.50	3031.50	Sloping embankments; vertical/sloping abutments			
11	Water-surface elavation at contracted section			3028.00	3028.00	3028.00	Left slope	NA	Right slope	NA
12		Fall in Water Surface (delta h) =				3.5	Type of abutment:		Type 2	
13							alpha =	summation[(K^3/a^2)]/(Ktotal^3/Atotal^2)		
14	Approach Section - Section 1									
15	Subsection	n	1.486/n	a	w.p.	r	r^2/3	K=(1.486/n)*ar^2/3	K^3/a^2	alpha
16	1	0.043	34.56	3133.89	515.18	6.08	3.33	360,896	4,786,055,150	1.00
17										
18		Total		3133.89	515.18		$K_{1(t)}$ =	360,896	4,786,055,150	
19										
20	For computing m only									
21	a	0.048	30.96	804.35	116.61	6.90	3.62	90,233	1,135,563,678	1.04
22	q	0.053	28.04	524.87	57.73	9.09	4.36	64,102	956,128,334	
23	b	0.048	30.96	1804.68	340.84	5.29	3.04	169,723	1,501,147,048	
24		Total		3133.89	515.18		$K_{1(m)}$ =	324,058	3,464,981,187	
25										
26	Contracted Section - Section 3									
27	Subsection	n	1.486/n	a	w.p.	r	r^2/3	K=(1.486/n)*ar^2/3	K^3/a^2	alpha
28	1	0.055	27.02	372.97	121.71	3.06	2.11	21,260	69,077,459	n/a
29										
30										
31										
32		Net total (minus piers)		372.97	121.71		K3=	21,260	69,077,459	
33										
34						**Items and Ratios**				
35	delta-h	3.50								
36	bt	55.89	width of the bridge opening/HWM		t	0.94		m=1-(Kq/($K_{1(m)}$)	0.80	
37	b	55.89	dist. between abutement faces		A_3 (Gross)	390.99		L/b (left)	1.00	L/b (right)
38	L (left)	55.89	width of the bridge + x		Y_3	7.00		r/b	na	
39	L (right)	55.89	width of the bridge + x							
40	Lw	69	Distance from app sec to upstream side of contraction		Ai	18.02		w/b	n/a	
41	r	n/a	radius of entrance founding		sigma	na		x/b (left)	0.00	x/b (right)
42	e	0.53			theta	0		(Ya+Yb)/2b	0.041	
43	x (left)	0			Ka	90,233		t/(y3+delta-h)	0.0898	
44	x (right)	0								
45	Ya	1.80	depth flow at embankment		Kb	169,723	See SVB Memo 74.14	F=V_3/sqrt(g*y_3)	**0.60**	
46	Yb	2.75	depth flow at embankment		Kq	64,102		j=Ai/A_3	0.046	(A_3 incl. piers)
47	g	32.16	acceleration of gravity		$K_{1(m)}$	324,058		e=Ka/Kb	0.53	
48	Ld	0	spur length - ** right side only		Ld/b	0.00				
49										
50										
51	**C**	C'	Kt	Kx*	Kd*	Kj	Ke	Emb slope		
52	**0.825**	0.86	0.997	*	*	0.962	1	2 to 1	C (right)	
53	**0.825**	0.86	0.997	*	*	0.962	1	2 to 1	C (left)	
54			* K values included in C' calculation for greater than 2 to 1 slopes							
55	**Ccomp =**	(C-left*Ka+C-right*Kb)/(Ka+Kb)		=	**0.825**					

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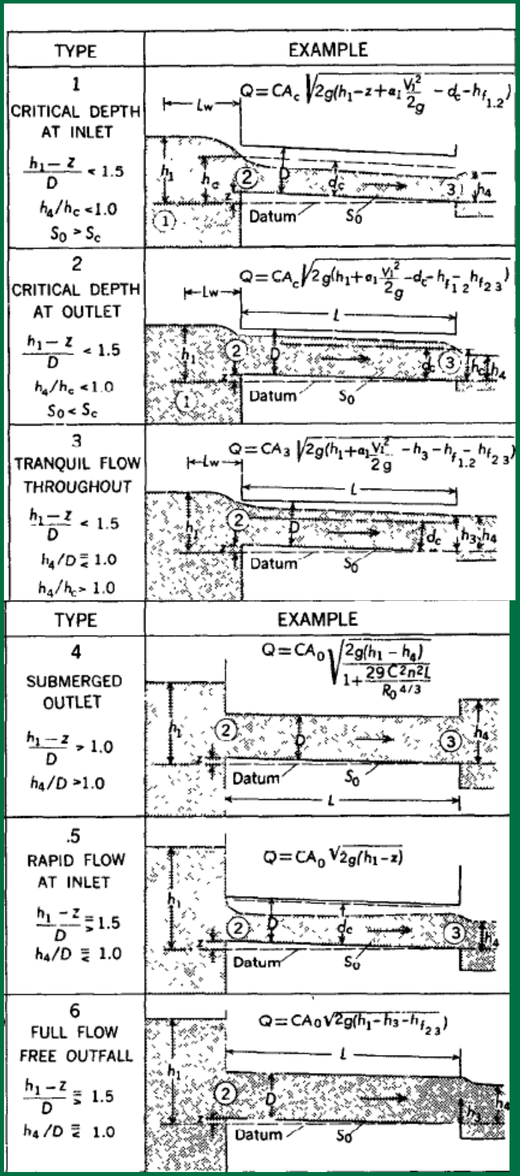
Culvert Computation

- Energy loss through culverts
- Site data:
  - Headwater elevation
  - Tailwater elevation
  - Culvert slope
  - Culvert geometry
  - Culvert roughness
  - Culvert entrance
  - Approach geometry



Flatwillow Creek near Flatwillow

- 2 Culverts
- Road overflow

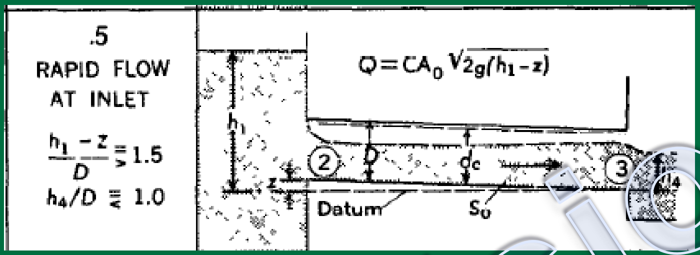
- Survey data
  - Approach section
  - Culvert geometry and elevation
  - Road centerline and cross section
  - HWMs-

    Upstream, downstream, outside road overflow influence

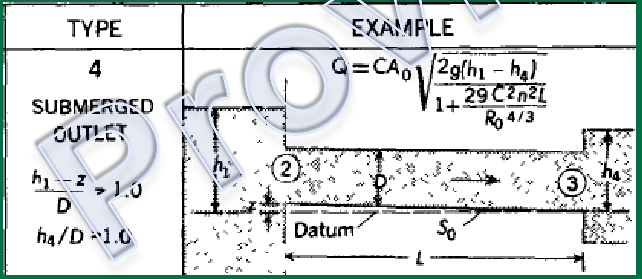
USGS

Flatwillow Creek near Flatwillow

- Culverts
  - Culvert analysis program (CAP)
  - L. Culvert=635 cfs



  - R. Culvert=940 cfs



- Road Overflow
  - Broad crested weir equations
  - Road overflow=935 cfs

Q Total=2,490 cfs

Need an indirect?

- **Surveys**
  - **Survey early!!!!!!!!!**
  - **Obvious? - look higher**
  - **Survey multiple high water marks**
  - **Pictures and notes**
  - **Flag marks**

Questions?

Gibson Dam on the Sun River
June, 1964

Photograph taken by George F. Roskie, Lewis and Clark National Forest

Swiftcurrent Creek at Many Glacier, GNP
November 7, 2006

Photograph taken by Don Bischoff, U.S. Geological Survey, Helena, MT.